I INTRODUCTION

Your new Model XF25-1563 Arc Reflection system with radar v.2 was designed to provide accurate cable fault location on primary underground cable. All components have been built and carefully tested to give you years of trouble free service.

We, at the VON Corporation, are constantly trying to improve our equipment. We would appreciate any comments or suggestions which you may have.

We hope you will share any techniques or applications you find especially useful with us, so that we may share them with all VON users through application notes and instruction manual changes.

Please keep us informed of the names of personnel to receive application notes and instruction manual changes.

For any questions concerning this equipment or its application, write or call:

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It is extremely important that the operator practice using the radar in this system before attempting to use it on an actual cable fault. Suggestions on setups to practice on are contained later in this manual.

II RECEIVING AND CHECKING OUT

The Model XF25-1563 is packed to arrive in good condition. Remove stretch wrap and check to see that there is no physical damage or parts which have come loose during shipment. A reel of cable at least 50 feet (15m) long is required to check out the unit. A roll of RG-58 works very well for this purpose. Two or three reels of URD cable connected together can provide longer lengths. If there are questions about the instructions which follow, see Section VI for more information and sample radar screens. Ground the cabinet using the green ground cable provided to the system neutral or building ground if inside. Connect the output lead of the system to the test cable.(Red lead to the center conductor and green lead to the neutral. Turn the RADAR-THUMP selector switch to the **RADAR** (Arc reflection method) position.

1. Turn the unit **ON** to view the cable with the radar. Units with Autorange software will momentarily show a screen that says “AutoAnalyze cable, wait one moment.” The unit will then show the cable with the right marker at the end. If the unit does not have autorange software or the end is not marked correctly, push the "RANGE" button until the “brick” on the right side of the screen lines up with the word RANGE, and increase the range with the ARROW keys until the typical up blip for the far end of the test cable is observed. With a jumper, ground the clamps at the end of the HV output lead and watch the display as the “up” blip changes to a “down” blip. The left point where the two waveforms diverge is the end of the HV lead and the beginning of the test cable. If the left marker does not already line up with this point, consult with the factory.

2. Now connect the conductor at the far end of the reel of test cable to its neutral or shield with a jumper. Observe the leftmost point at which the two traces diverge. The up blip at the open end will have an identical down blip from the short. The leftmost point where the two blips change direction is the end of the cable.

3. Make a gap at the far end of the test cable between the center conductor and the cable shield to simulate a fault which can be impulsed (thumped). A distance of .0625" (1.5mm) to .188" (5mm) will do fine for this gap. When additional cable is available, it may be connected to the test cable at this point so the fault will not be exactly at the end. Temporarily short the gap with a jumper and observe the radar screen. Remove the short at the gap.

4. Set the voltage to 12.5kv. Push the **START** button. A second trace(reference) will appear at the top of the screen and the words “WAITING FOR THUMPER” will should appear above it. The voltage should rise to the set voltage and then discharge. When the gap fires, the bottom screen should change. The fault will have a down blip just like when a shorting lead was placed from the center conductor to the shield at the same point. The top reference trace is the cable without the short created by the arc. The left point where the two traces diverge is the fault. By putting the right marker at this point the distance to the fault can be determined. If the gap is too large at the simulated fault, the capacitor will not discharge and the voltage will not fall. In that case, push the **STOP** button , set the voltage on 25 kv. Push the **START** button twice to try again. The words “WAITING FOR THUMPER” should appear.

III SAFETY

Personnel safety is a most vital concern when testing and fault locating. Only qualified electrical personnel should operate this equipment. Always follow your company's safety procedures. If any recommendation in this manual conflicts with your company's safety procedures, contact the factory for clarification before operating the equipment.

The wearing of insulated safety gloves is strongly recommended while fault locating and must be worn when making or breaking connections to the faulted cable being worked on. ALWAYS ground the faulted cable with a properly sized grounding set before touching the cable termination and making connections to this equipment .

<u>Always ground</u> the cable to be fault located upon before connecting or disconnecting this unit. This equipment is designed to be used on unenergized cable only. Connecting the equipment to an energized cable causes severe equipment damage and is very hazardous to the operators.

While using this equipment, all terminations of the cable being worked on must be roped off or otherwise protected so that the unaware can not come in contact with them.

In fault location, grounding is the most important concern and safety precaution. The heavy green ground lead must be connected to same ground system to which the faulted cable neutral is connected. <u>BEFORE USE</u> **ALWAYS** check to insure that the high voltage output is tied to the center conductor of the faulted cable and the green high voltage return is connected to the faulted cable neutral.

THE MOST IMPORTANT SAFETY FEATURE: A full recognition on the part of the operator of the inherent danger always present with the use of high voltages will be the most important safety feature that can be applied in the use of this equipment. Your operating procedures should be so designed as to minimize this danger. The operator of this equipment should be responsible for seeing that each member of the assisting crew is thoroughly familiar with the dangers involved.

This manual recommends that all grounds and neutrals be tied together for safety to present the lowest possible resistance to the return impulse. The impulse (thump) is similar to a lightning strike.

Some companies try to isolate the neutral of the faulted cable from the system neutral. This policy requires more than just disconnecting the cable neutrals at both ends of a concentric neutral cable. One must also isolate the impulse fault locator from the system neutral. To isolate an impulse fault locator from the power system neutral, it must be operated from its internal battery, a 12 volt D.C. inverter or a portable generator which is also isolated from the system neutral and only tied to the faulted cable neutral. Connecting the unit to an auxiliary driven or screw ground close to the case and separate from the system neutral is strongly recommended in this situation. If the auxiliary ground is not used, the tester case and the portable generator or truck are then treated as hot, since instantaneous voltage differences are likely to appear between the earth and the faulted cable neutral. The wearing of insulated safety gloves by the test equipment operator is mandatory when the unit is isolated from the power system neutral.

IV DESCRIPTION AND SPECIFICATIONS

The Model XF25-1563 v.2 consists of a thumper, a digital memory radar, an arc reflection method coupler(filter) and required switches in one self contained unit mounted on a hand truck with 16" (40cm) diameter wheels. The sealed unit is designed to be operated in most weather conditions from its internal 12 volt battery, an external 120 volt source or an external car battery.

Thumper Specifications

- Capacitor bank provides 1563 joules at both 12.5 KV (20 mfd) and 25 KV (5 mfd)
- Simplified controls: Pushbuttons: "START","STOP", Knob “VOLTAGE ADJUSTMENT”, Toggle switches "ON/OFF", "25 KV/ 12.5 KV", "RADAR / THUMP", and "BATTERY CHECK"
- Gap and all switches are electrically operated.
- 0-25 KV kilovoltmeter
- Discharge voltage preset to 12.5 KV or 25 KV. Unit can be discharged at other voltages using the VOLTAGE ADJUSTMENT knob.
- Thump interval 14 seconds in "THUMP" switch position

Radar Specifications

Distance

Digitally displayed on the display. The resolution is .5% of the range selected.

Ranges

0- 500, 1500, 3000, 6000, 12000, 24000 and 48000 feet (0-150, 500, 1000, 2000, 4000, 8000, 16000 meters) when using a velocity propagation factor of 50.0%. The ranges are selected by pushing the "RANGE" button and then the “UP” or “DOWN” arrow buttons.

Velocity Factor

Digitally shown on the screen. The initial turn on value of 53.0% can be increased or decreased to the desired value. The velocity factor can be set from 25.0% to 99.0%

Screen

LCD 3.5"(8.9 cm) x 4.5" (11.4 cm) with 320 x 240 dot matrix providing both trace and text. The display can be easily read in direct sunlight. A backlight is provided so the screen can be viewed in total darkness.

Memory

Nine memories are provided for storage of traces. Traces are stored using the options menu. A 9 pin RS232 port is provided for downloading traces to a computer which has installed the Radar Trace Storage Program.

HV Coupler

Matched to the thumper and radar to provide distance to the fault by using the arc reflection method. The large inductor in the coupler allows maximum energy transfer to the faulted cable.

Environmental

Operating temperature -25°F (-31°C) to 110°F (43°C). Sealed so it can be operated in the rain. The external battery inputs and 10 amp control fuses are protected by a rain shield and positioned on the left side of the unit at a convenient height. The radar screen is backlighted so the unit can be operated in total darkness.

Battery

The internal sealed lead acid battery provides for 30 minutes of continuous thumping. The internal battery charger has a regulated output so the unit can be left in the charge mode without damaging the battery. The external 12 volt DC input is protected against polarity reversal. The external 12 volt DC source is connected to the load in parallel with the internal battery and charges the internal battery through a current limiting resistor. The unit automatically switches from internal 12 volt DC to external 120 volt AC when connected to 120 volts AC.

Weight

250 pounds (114kg)

Leads

50 foot (15m) long shielded high voltage lead with male MC connector. A hot line clamp, vise grip and elbow adapter with female MC connector are provided to terminate the high voltage lead. Longer lengths and extra flexible EPR insulated X-ray cable are available.

15 foot (4.6m) #2 ground cable

V CONTROLS AND INDICATORS

ON- OFF switch operates the main power.

12.5 kV- 25 kV switch operates the motorized high voltage switch that changes the connections on the capacitor bank between the 12.5kv 20 mfd position and the 25kv 5 mfd position. The switch also sets the limit on the high voltage control.

RADAR-THUMP switch in the “RADAR” position provides power to the radar and operates the motorized high voltage switch that put the inductor in series with the high voltage output to the test lead. This position provides fault location by the arc reflection method. In the “THUMP” position the motorized high voltage switch directly connects the high voltage output to test lead and turns radar off.

START pushbutton - When the "START" pushbutton is pushed the motorized discharge switch opens, the motorized gap opens, and the high voltage supply begins charging the internal capacitor bank to the set limit. In the RADAR position, the “START” pusbutton toggles between arc reflection and radar modes. In the RADAR position the sentence "WAITING FOR THUMPER" must appear at the top, If “WAITING FOR THUMPER” does not show push the “START” pushbutton a second time. “WAITING FOR THUMPER” indicates the system is armed and can be triggered by a "thump" The trigger pulse from the thump starts the ARC REFLECTION SEQUENCE. After a very short delay which is controlled by the DELAY switch, a radar pulse is injected into the faulted cable. The resulting waveform is automatically transferred into the bottom trace.

STOP pushbutton- Drops out the high voltage ready relay which kills the high voltage supply, closes the motorized discharge device to discharge any internally stored charge, and after a delay closes the impulse control gap to discharge the output cable.

VOLTAGE ADJUSTMENT knob - adjusts the discharge voltage from a low value to the maximum voltage of 12.5kv or 25kv. This permits discharging at voltages less that the set maximum voltage to thump or to test.

Battery Check switch - toggles the meter to read the battery voltage. If the meter indicates in the Green region above the numbers, the battery should be adequately charged for use.

GAIN knob (on v.2 Manual Gain Control radars) - Provides vertical gain adjustment from 0 to 20 dB
or
GAIN button (on v.2A Automatic Gain Control radars) - Provides manual vertical gain adjustment from 0 to 20 dB by using the up and down arrow keys

OPTIONS pushbutton - Pressing the OPTION key presents a menu of available options such as delay and left starts. This button is not normally used during operation.

RANGE pushbutton- allows the operator to use the arrow buttons to change the range. The width of the transmitted pulse is adjusted automatically when the range is changed. When the power is turned on, units with autorange software will automatically attempt to find the end of the cable and select the appropriate range. If the software is unable to identify the end of the cable or autorange software is not installed, the default (normally 500 foot/150m) range is automatically selected. The current range is displayed in the bottom right hand corner of the screen.

PULSE WIDTH pushbutton (v.2 Manual Gain Control radars only)- This allows the operator to adjust the pulse width so he can pick out splices or transformers which are close together.

ARROW ?= / <> pushbuttons- Changes the function where the “brick” or onscreen < is located.

RIGHT MARKER pushbutton - Allows the operator to use the arrow buttons to move the right vertical line. The vertical line on the right of the display that sets the end point for all measurements.

LEFT MARKER pushbutton - Allows the operator to use the arrow buttons to move the left vertical line. The vertical line on the left of the display sets the beginning point for all measurements. When the radar is turned on the left marker is put at the saved end of the test lead position. This setting is changed via the options menu.

VELOCITY pushbutton - Allows the operator to use the arrow pushbuttons to adjust the velocity factor. Adjust velocity factor as needed to match the faulted cable. When the unit is initially turned on, the radar is automatically set to the default VF of 53% (Correct for most primary cable)

TRACE pushbutton- Allows the operator to use the arrow pushbuttons to move the bottom waveform up and down.

CONTRAST knob- This control adjusts the LCD background intensity and allows the operator to optimize the contrast of the display for the particular viewing conditions such as direct sun or shade. The backlight is always on.

LCD DISPLAY - All information is displayed on this screen. The number in the bottom left corner is the distance between the two markers. The number in the bottom center is the velocity factor. The number in the bottom right corner is the current range. When a single trace is shown (active radar mode), it is “active” and shows what the unit is currently connected to. When two traces are shown (arc reflection mode), the top trace is a stored “reference” trace and the bottom trace is the “captured” trace from the arc.

FUSEs are next to the external 12 volt input. When one is present, it is a 12V control fuse. When two are present, the top on is the 12V control fuse and the bottom one is the 120V AC fuse. The 12V control fuse is rated 10 amps slow blow and disconnects power from the control circuit and motors. The 120V AC fuse is rated 10 amps slow blow and disconnects the AC input cord from the 120V AC internal wiring. The fuses are intended to limit and damage due to a component failure or short to the case. Remove the fuses when taking off the control panel for maintenance.

VI-A OPERATION- RADAR - ARC REFLECTION METHOD

Practice in a test situation with the radar before field use is very important. Be sure that you know how to locate the end of the units test lead with the radar before connecting to a faulted cable. Sample traces in various situations are provided in sections VI-A through VI-H. Step by step fault location traces are provided in sections VI-B and VI-C.

1. Remove all the green ground cable and uncoil it. Route the cable without loops to the system neutral and tightly fasten its clamp to the ground grid where the faulted cable neutral is connected. Connect the output lead of the system to the faulted cable. The output lead can be terminated with a hot line clamp, vise grip, or feed through adapter since MC connectors are provided. Be sure the ground return clamp (normally painted green) fastened to the shield of the coaxial HV output cable is connected to the neutral of the faulted cable as close to the cable end as possible. This connection should be closer to the faulted cable than the green safety ground. Connect the center conductor of the HV output lead (normally marked with red) to the center conductor of the faulted cable.

2. The unit can be operated from its internal battery, an external battery, or 120 volts AC. To operate from an external battery plug in the battery leads to the DC power input connector and then connect to an external battery. To operate from 120 volts AC connect to a 120 volt source.

3. Turn switch to the RADAR position and then turn the unit ON. If the trace does not show up adjust the SCREEN CONTRAST knob to match the reflectivity of the LCD screen to the background light. Slowly turn SCREEN CONTRAST knob full clockwise and then counterclockwise until the trace is most visible.

4. Identify the far end of the cable under test. When the unit is turned on, units with Autorange software will automatically attempt to mark the far end of the cable. Always look at the trace to see if you agree with the software. Units without Autorange software will go to the default range (normally the lowest, 500 feet/150 meters). Increase the range until the upward blip typical of the open end is seen on the display. The relative size of the blip depends on the length of the cable and how much pulse energy is absorbed by the cable. To <u>increase</u> the range: first push the Range button, then press the up Arrow button. If the you pass the range that puts the cable end closest to the right side of the display, push the “DOWN” arrow button until the desired range is selected. As the ranges get longer the amplification normally needs to be increased with the GAIN knob.

   If a downward deflection is seen instead of an upward deflection, either the end of the cable is shorted or there is a grounded fault in the cable.

   To verify that a given upward blip is the cable end, alternately ground and open the far end while observing the display. The end blip will be downward when the end is grounded and upward when it is open.

   Normally the far end has a distinctive up blip and is the highest up indication on the waveform. If the cable has a fault with low resistance (less than 200 ohms at 10 volts) a down blip will appear at the fault. The far end of the cable will not show past such a low resistance fault.

If no down blip is observed when the far end is short circuited, the cable conductor is open
at the fault. Set the right marker on the beginning of the left "up" blip indication of the cable end to determine the distance to the open circuit. Determine distance to the open from the opposite end of the cable for better accuracy. Pinpoint the fault by "thumping".

5. Normally the voltage is set to 12.5kv for the first attempt. Keep the selector switch in the RADAR position to provide a one shot inpulse through the inductor. In the RADAR position the unit is designed to provide one thump at full voltage. The maximum voltage can be adjusted using the VOLTAGE ADJUSTMENT knob. With the entire faulted cable on the display, push the **START** button until the sentence “WAITING FOR THUMPER” appears on the top of the display and the thumper will start charging up to the selected voltage. When the gap fires, the ARC REFLECTION SEQUENCE should begin in the radar and a new trace made during the arc will appear at the bottom. If the voltage does not drop to near 0, the fault has not arced over. Push STOP and try again in the 25 kv position. Remember that after each impulse, the START button must be pushed twice or until so the radar screen shows “WAITING FOR THUMPER”. If the voltage drops and the traces are identical, there may be transformers on the cable.

6. On cable without transformers connected, the unit makes a rather deep sound when there is a successful impulse and a small tick sound or no sound when the impulse is not arcing over at the fault. On cable with transformers connected the sound inside the unit is the same for a good cable and a faulted cable. If the radar pulse that was sent out by the trigger circuit arrived a the fault while it was arcing over to ground the bottom memory will contain the trace of the cable showing a low impedance down blip at the fault. If both displays are the same, repeat at 25kv. Two approaches are available if the radar does not still indicate the fault.
a. Push **STOP** button. Then turn the unit to the **AUTO THUMP** position. Push **START** to "thump" the cable five or six times. Push **STOP** button. Then turn the selector switch to the **RADAR** position, set the proper range, and push **START** to try the arc reflection method again.
b. Connect to the faulted cable from the opposite end and try again.

7. After a successful impulse on the cable, the bottom trace will be identical to the top trace until the location of the fault. At that point the bottom trace will diverge and change shape from the top reference trace. The first left hand point at which the two traces diverge is the fault. (After the divergence the two cable waveforms do not match up) Units with Autolocate software will attempt to automatically mark this point. With all units you can manually determine the distance to the fault by setting the left and right hand markers. The left marker is normally preset for the end of the test lead and the beginning of the faulted cable. This eliminates the need to subtract the apparent lead length from the distance shown. The right marker is normally adjusted to the location of the fault to give the distance to the fault from the hook up location.

Distance measurements are displayed in the lower left portion of the display which represent the distance between the left marker and the right marker.

8. Push the **STOP** button to discharge the cable and the internal capacitor.

9. When the fault is closer to the far end of the cable, it is normally easier on the person doing the final fault location by the "thump" sound to determine the distance between the fault and the far end of the cable. This can be done two ways. One method is to set the right marker to the end of the cable and the left marker to the fault. The distance from the far end can then be read directly from the bottom left corner of the screen. Another method is to note the distances to the far end of the cable and the fault as determined in step 7. Subtract the two distances to obtain the distance to the fault from the far cable end.

10. When the pinpointing person reaches the approximate location determined by the radar switch the unit to the THUMP position. Normally the final fault location can be determined with only a few thumps. In the **THUMP** position the unit will thump every approximately every 12 seconds. If the operator wants to thump at a lower voltage he may use the VOLTAGE ADJUSTMENT knob to set the desired voltage. Locating your cable path can greatly assist in this step. If transformers are connected to the system, they must be disconnected or have their fuses pulled before pinpointing.

VI-B HINTS AND TYPICAL TRACES

1. The radar must show the faulted cable ends before any attempt is made push the START button which automatically puts out a high voltage pulse.

2. Remember that the magnitude of down blip at the fault can not be greater than the magnitude of the up blip due to an open circuit at the same point.

3. If different types of cable are spliced together, the trace itself can go up or down after the discontinuity at the splice.

4. The first step in locating a fault using radar is to find both ends of the cables. This is done by touching each end to ground and finding the left most point where the trace changes direction.

5. Notice that locating the beginning of the cable by shorting it to ground requires the most skill. Everything past the fault changes.

6. Notice that a short at the end of the cable is easy to find and locate. Figure 11 shows the cable shorted continuously at the far terminal. Figure 12 shows the fault as it looks while arcing over a gap at the end using the arc reflection method.

7. Remember that the first major divergence between the reference trace and the active trace is what you are looking for. The down blip at the fault may not be down on the screen but only below the REFERENCE trace. In some faults at the divergent point the ACTIVE trace is a straight line while the REFERENCE trace goes up. This is most likely to happen on very short cable where the cable trace

is very wavy.

8. When the cable trace looks similar to the trace of the end of the test lead alone then the faulted cable is very short (most likely burned in two pieces) Very short runs have a large number of ups and downs in the waveform.

VI-C DETERMINING DISTANCE TO FAULT WITH TWO OR MORE CABLE TYPES BETWEEN TERMINALS

When two types of cable are spliced together that have very different velocity factors (i.e. PILC and XLPE spliced together), Arc Reflection accuracy can be greatly influenced by the VF. The distance to the fault can only be accurately determined if the distance is measured using one cable type and it's associated VF. For example if the first portion of a cable run is paper lead cable (VF=38.0%) and the remainder is XLPE (VF=53.0%) the distance to the fault in the paper lead cable can be determined from the front end using a VF of 38.0%. The distance to a fault in the XLPE section can be determined from the far end using a VF of 53.0%. Normally the radar shows the transition between cable types with the trace either rising or falling so the operator can guess in what type of cable the fault is located..

It is not possible to accurately determine the distance when measuring through one type of cable into another type of cable with very different velocity factors (i.e. XLPE spliced in the middle of a run of PILC). Several approaches are available to get reasonable distances..

1. Determine the distance to the fault using the VF of both cable types. The actual fault will be somewhere between the distances determined with each VF.
2. Use an average of the VF of each cable type if their VF is similar. An example is when EPR cable is spliced into XLPE polyethylene cable .
3. Look at the cable trace and determine the front end and far end of the faulted cable. Determine visually where the cable fault is as a percent of cable length. This percentage will always be correct. Use the percent of cable length to determine where to start listening for the thump.

VI-D RS232 PORT

An RS232 port is provided on the left side of the unit just above the 12 volt DC input. It can be used to connect to a computer running the optional trace download software. Additional instructions are included with the software.

VI-E TESTING CABLE

Use the THUMP position to test cable. The voltage may be adjusted using the VOLTAGE ADJUSTMENT knob. In the THUMP position push the START button. If the cable is good, the voltage will not drop significantly when the gap closes and connects the internal capacitor bank to the external cable. A small voltage drop is expected on good cables proportional to the length of the cable due to charging current of the cable. Push the STOP button to discharge the internal capacitor and the external cable.

VI-F SECTIONALIZING URD LOOP SYSTEMS

The arc reflection system is a new method for determining the faulted cable section without opening each transformer cabinet. By connecting the XF25-1563 at the open cutout or at a center transformer cabinet the operator can determine the distance to the cable fault using the radar. Then the faulted cable section can be disconnected and all customers can be returned to service. When all customers are returned to service the XF25-1563 can then be connected to the faulted cable and the distance to the fault determined using traditional methods.

Some customers have expressed concerns that putting an arc reflection pulse on the source side or transformers feeding customers would send damaging pulses into the customers system. Only a small percent of the energy can go through the transformer. Since the XF25-1563 is rated 400 watts and typically the customers connected are attempting to pull many thousands of watts there is no way that damaging pulses can get into the customers system.

Currently the most popular approach to sectionalizing using an arc reflection system is to open a transformer halfway between the pole and the open point. The arc reflection system is then connected to both pieces of the circuit one at a time to determine where the fault is located. The 12.5kv setting has been found to work best. If both traces are identical on a run then it does not have a fault and can be refused. The arc reflection system will not locate internal transformer failures so if the fuse blows each transformer in that section should be inspected for failure. The arc reflection system should be connected to the second section and impulsed using the “START” button. The low voltage radar pulses alone can be used to verify that the faulted cable has been disconnected from the system so that power can be restored to the customers. The location of the fault can then be determined using radar and the thumper after the faulted cable is disconnected from the system and power is restored to all customers.

VI-G RADAR OPTIONS MENU

The options menu allows you to change the default settings and access advanced features. This menu is not normally used in day to day operation of the equipment. The available options are different depending on the firmware revision. Please follow the onscreen instructions for your specific firmware revision. On the left side of the screen, the available functions are listed. On the right side of the screen the buttons corresponding to each function is shown in [ ].

Initial Options Menu

Upload Screen Data - This button is used to download the active trace or traces to a computer using the optional RS232 cable and software. Additional instructions are included with the software.
Time Delay is now ?? / Default Delay is ?? - This is an indication of the current and default time delay. The time delay is reset to the default when the power is cycled.
Increase Delay Time / Decrease Delay Time - These options increase and decrease the currently used time delay.
Memory - This setting allows access to the internal memory via the Memory Menu.
Default/Setup - This setting allows access to the Default and Setup Menu.
Change Pulse Width - On Autogain (v.2A) units this allows the user to change the pulse width.

Memory Menu

*Select Active Mem **?*** - This setting toggles the "Active" memory which is displayed in place of the ?.
Save lower trace in memory - This setting saves the lower or active trace in to the active memory.
*Toggle Display Memory *Off** - This setting toggles onscreen display of the active memory.
MEM STATUS 0=OPEN, 1=SAVED PREVIOUS
MEM #1 #2 ... #9
STAT 0 0 ... 0

This section displays the status of each of the nine memories. A 0 under the number indicates no trace has been saved. A 1 under the number indicates that there is a trace saved in that memory.
Reset Active MEM status to 0 - Deletes the trace in the active memory.
Reset all Memory Status to 0 - Deletes all traces stored in the radar.

Default and Setup Menu

Velocity (VF): to set the default VF to current VF Press... - Use this option to save the current VF setting as the default turn on VF.
Range: to set the default range to the current range press... - Use this option to save the current range setting as the default turn on range. This setting only is active when Autorange is turned off or not installed.

Set left marker start point... - This option returns to the radar trace in the 500 foot (150m) range. Use the arrow buttons to more the position of the left marker to the end of the test lead. The location of the end of the test lead can be precisely located by alternately shorting and opening the end of the test lead while observing the display to find the point where the trace changes. Follow the onscreen instructions to lock the setting in (usually by pressing the Left Marker button).

Go to Auto-Range/Locate Setup... - This options allows access to the Auto-Functions Setup Menu.

Auto Functions Setup Menu

*Auto-Range as Default *Yes** - This option allows you to turn the Auto-Range software off or on.
*Auto-Locate as Default *Yes** - This option allows you to turn the Auto-Locate software off or on.

VII IN CASE OF DIFFICULTY

Shock off case of unit	Indicates the heavy ground lead has not been connected to the system neutral. STOP! Immediately connect green case ground cable to ground rod (System neutral) to which the faulted cable neutral is connected without loops or coils in the cable. **The ground return clamp at the end of the HV test lead must be connected closer to the faulted cable neutral than the case**

	ground clamp!
Arcing sound near ground (green) hot line clamp on end of test lead.	STOP! Determine location of arcing and correct problem. 1. Check that the ground conductor has not broken where it is connected to the hot line clamp. Repair before continuing since thumping into the "case ground" instead of the isolated return will cause the noise level at the fault to be very low, may keep the arc reflection system from working, and will likely damage the unit. 2. If arcing is between the ground clamp and the cable neutral tighten clamp. If tightening does not solve problem then remove clamp, clean corrosion from the cable neutral, and tighten clamp again.
Voltage rises to limit but does not discharge	Insure case is tied to system neutral with the heavy ground lead. Timer for gap becomes erratic and resets itself when the case is ungrounded. STOP! Immediately connect green case ground cable to ground rod (System neutral) to which the faulted cable neutral is connected without loops or coils in the cable. **The ground return clamp at the end of the HV test lead must be connected closer to the faulted cable neutral than the case ground clamp!**
The voltage on the capacitor bank does not begin increasing when the START button is pressed.	1.Check 10 amp control fuse located just above the external 12 volt DC input on the left. 2. Indicates the inverter may be in trouble. Check the unit for proper operation using 120 volts AC and using an external battery. If unit works on AC but not on DC either the inverter has failed or its MOSFET switch. Contact factory for guidance. 3. If unit does not work with any power source, check for loose connections.
Radar does not turn on	Adjust contrast knob to display screen by slowly turning full clockwise and then counterclockwise. If a waveform does not show up: 1. Plug unit into 120 volts to operate. The unit will normally operate even when the battery is low when connected to the 120 volt input. 2. Connect the unit to an external 12 volt battery such as a car or truck battery. Connect red terminal to positive and black terminal to negative. 3. If the unit still will not work remove 10 amp fuze located just above the 12 volt input on the left side. Take control panel off by removing the three screws in the top aluminum holding bracket and loosening the three screws in the bottom aluminum holding bracket.

	Someone will have to hold the control panel or a support will have to be provided. Check radar input fuse. Check for loose wires or screws before installing spare fuse provided. Put panel back in place, install 10 amp fuse, and retry. 4. If the above steps do not solve the problem contact factory for guidance.
Radar does not display faulted cable near end and far end.	1. Verify that you are on the proper range. (A 500 foot long cable does not show up well on the 10,000 foot range.) 2. Check to see if you can see the end of the test lead by shorting the ends of the lead together and watching the waveform change. If there is no change in the waveform look for connections which have come disconnected and reconnect. Contact VON plant in Birmingham for guidance.
Radar does not trigger	1. Push the STOP button and then try again by pressing the START button twice The sentence "WAITING FOR THUMPER" must show on the screen. 2. On rare occasions the faulted cable will absorb the pulse and no signal will reach the radar to initiate the trigger. Then a. Increase the voltage level of the impulse b. Decrease the voltage level of the impulse c. Connect unit to opposite ends of the faulted cable d. If none of the above works locate fault by sound alone without using radar. If this doesn't work cut the cable at the convenient place to break it into smaller pieces. Try the arc reflection system again. 3. Check for loose connection between aluminum frame and the rear of the radar. The braided copper connection must be tight. Remove the six mounting screws which hole to control panel to the unit in order to inspect the ground connection.
Radar does not display two traces which diverge at a point indicating the fault location after an impulse.	Usually means you are on a good cable. Check to insure you are not on a good cable. The unit will pulse once on a good cable without transformers connected but the voltage will not drop to zero. On a second thump the voltage will not drop at all on a cable without transformers connected.. A. Push the STOP button. Then push the START button twice and be sure the sentence "WAITING FOR THUMPER" appears at the top of the screen before another impulse. Push the STOP button after the unit

discharges.
B. If this does not work, pushing the START button twice again and decrease the voltage of the impulse by turning the VOLTAGE ADJUSTMENT knob to half voltage. If it doesn't discharge adjust for a higher voltage). Push STOP button after the unit discharges since the unit will immediately begin charging again since it has not discharged once a the maximum voltage setting..
C. If this does not work, increase the impulse voltage of the impulse by going to the 25kv position and pushing the START button twice again.. Push STOP button after the unit discharges.
C. Switch to THUMP position and thump the cable a few times. Then try to utilize the radar by switching to the RADAR position and pushing the START button twice to get the sentence "WAITING FOR THUMPER" and to pulse the cable again. Push STOP button after each attempt.
D. Look at faulted cable from the other end. This may help if the cable neutral is not in good condition.
E. Try 12.5 kv position which has a larger capacitor bank which will increase the current flow duration.
F. If the arc at the fault can only reach the cable semicon instead of the metallic neutral, the fault resistance will likely not be lowered enough to be seen by the radar. Increasing the voltage of the thump may allow the arc to reach the metallic neutral.
G. On long lengths of cable, the capacity of the impulse capacitor must be several times larger than the capacity of the faulted cable for a good arc at the fault.

The unit discharges but both traces are identical.	This indicates that the triggered pulse arrived before or after the low resistance was formed by the arc. This indication occurs when you thump a good cable. It may also indicate the resistance in the arc was too high for the impulse voltage used.
The bottom trace has a ragged look.	A ragged trace is not to be trusted since it indicates a stable low impedance had not been established at the fault by the high voltage pulse when the radar signal arrived. (See section VI for some example traces.) Push the **STOP** button and then the **START** button twice to re-arm the system for another ARC REFLECTION SEQUENCE. If this does not provide the fault location, try a lower voltage impulse and then a higher voltage impulse. Adjust the delay by going into the OPTIONS menu.

Up blip at far end of the cable does not change direction when shorted.	Indicates an open center conductor or an open neutral in the cable between the operator and the far end of the cable.
Radar indicates a down blip where the HV lead attaches to the faulted cable	If the characteristic impedance of the faulted cable is much less than the HV lead, the radar blip will go down instead of up. May be a close in fault or the safety ground was left on the terminal.
Radar indicates an up blip where the HV lead attaches to the faulted cable.	This is normal since the separation of the center conductor and the shield at the end of the test lead has a high impedance. The up will be stronger if the characteristic impedance of the faulted cable is higher than the test lead.
Multiple faults are indicated	Normaly only one fault shows up with each impulse. Each location should be checked using the impulse fault locator (thumper).
Up blip at far end of faulted cable is not visible.	Check that maximum range of radar is longer than the cable. Adjust radar to higher range. Bad neutrals on a cable can attenuate the radar signal so much that the far end is not visible. On long cables with multiple taps only the ends of the first few taps will normally be visible.
LCD screen blacks out when stored directly in the sun.	When the display gets too hot it turns black. It will quickly recover if it is protected from direct rays of the sun by a cover for a few minutes which allow display to cool. Avoid leaving the LCD screen in the sun longer than necessary as it can be permanently damaged.
The backlight comes on but there is no waveform on the LCD display	a. Adjust the contrast control slowly in both directions b. Check internal battery voltage with battery check switch. If below 11 volts connect to an external battery to insure there the unit is getting 12 volts DC. Plug into a 120 volt outlet.
Unit does not operate from internal battery.	Check that battery voltage is okey. If no voltage is indicated remove large front cover for access to the battery which is located in the right rear bottom of the unit. Check 50 amp fuse located just above the battery on the inverter mounting plate. Check with factory for guidance.
Trace on radar goes up and down rather violently	Normal indication when radar is connected to a short run of cable less than 100 feet long. See traces in section XI that show the waveforms obtained when looking at just the test lead of the unit.
Unit makes a beep when turned on and turned off.	Normal sound caused by the low battery indicator operating as the power is turned on or turned off to the circuit board.

Beeping sound when unit is charging up to 12.5 kv or 25 kv	Caused by battery voltage falling below 10.5 volts while charging. This is a normal indication the unit is working. When beeping sound is continuous or unit will not get to voltage you must: a. Connect the 120 volt input cord to a 120 volt source.. b. Plug in the battery leads into its receptacle located on the left side of the unit and connect up to a truck or car battery c. When battery gets close to 10.5 volts the unit will not charge to full voltage. The gap can be fired at a lower voltage with the VOLTAGE ADJUSTMENT knob when the supply is unable to get to full voltage. BE SURE to immediately charge the battery after using at low voltage.
Radar trace looks ragged and unclear	1. Try again and fire at lower voltage using the VOLTAGE ADJUSTMENT knob. After it fires hit the STOP button. Then rearm the radar by pushing the “START” button twice for another discharge. 2. Go to the options menu and set the delay to a higher value. Try again.
Unit almost reaches voltage and then gets stuck	Indicates the battery voltage is dropping very low while charging up the discharge capacitor. Verify by pushing the battery check voltage while the unit is charging. Unit can be operated by turning the VOLTAGE ADJUSTMENT knob counterclockwise to discharge the capacitor at a lower voltage. Operate the unit from 120 volts AC or an external car battery.
Time between thumps exceeds 20 seconds	Indicates the battery voltage is dropping below 10.5 volts while charging the capacitor or the unit is operating without a ground on the case. a. Check that the green ground lead is connected to the same ground rod that the faulted cable is connected. If a temporary screw ground is used connect it to the faulted cable ground rod with a heavy jumper b. Push the battery check switch to determine if this is a problem when the unit begins to charge the discharge capacitor.
Nothing comes on with internal battery, external battery, or AC	Indicates 10 amp control fuse to limit damage on component failure has failed. Remove six screws which hold on the control panel. Look for any loose wires that may have shorted to the case and tighten into position. Replace front panel and then replace fuse.
Motors start and do not stop with START button is pushed.	a. Normal indication when START button is pushed immediately after pushing the STOP button. Push STOP button down until motors stop. b. Turn unit off. After 30 seconds, turn unit on. If motors continue to operate it indicates a limit switch on the switch motors has gotten out of adjustment. Remove 10

	amp control fuse located just above the external 12 volt DC input on the left side to keep from running down the battery. Locate and fix the problem. .As a last resort remove the rectangular front cover with round window and remove the 50 amp fuse in series with the positive battery lead.
Female MC connector will not unmate from the male MC connector installed on the end of the test lead.	Indicates something sticky like flux may have gotten under the locking ring on the male connector. The small ring must slide easily in order to unlock the connection. Soak the connector in a solvent such as acetone or laquer thinner until the contamination loosens enough for the ring to slide.
The capacitor does not start charging up with the START button is pressed.	1. Check 10 amp fuse on left side and replace if defective. 2. Indicates the inverter may be in trouble. Check the unit for proper operation using 120 volts AC and using an external battery. If unit works on AC but not on DC either the inverter has failed or its MOSFET switch. If unit does not work with any power source, check for loose connections. Contact factory for guidance. 3. Check at other voltage setting to insure problem in not due to limit switch on 12.5/25kv switch motor.
Gap motor on left front side operates a short time after the discharge motor closes	Normal operation. The internal capacitor bank is first discharged through a 5,000 ohm resistor before the external cable is discharged by the same resistor when the gap closes.
Bottom trace in “Waiting for thumper mode” goes to a straight line.	Indicates poor ground connection between radar case and main case. Turn radar off and then back on to reset radar. To repair ground remove two aluminum angles that hold top control panel to the case. Carefully pull control panel out. Clean and then tighten connection points where copper braid connects the aluminum case of the radar to the side of the enclosure.

VIII TEST LEADS, BATTERY MAINTENANCE, AND STORAGE

The high voltage test lead is provided with a male MC connector. This allows the lead to be terminated with a hot line clamp, vise grip, or elbow adapter. Push the male connector into the female to release the locking connection. Be careful to insure the sliding ring of the male probe stays movable. Any substance which causes the ring to not move will prevent the female connector from being removed from the male. The high voltage lead is available with RG-8U polyethylene cable or EPR x-ray cable.

The ground lead must always connected to the neutral bus! Be sure to pull all the cable out of the storage area and lay on the ground such that there are no loops.

The internal sealed lead acid battery should be kept charged to at least 11.5 volts during storage since it can be severely damaged if stored below 10.5 volts. The internal battery charger regulates the voltage at approximately 13.6 to 13.8 volts so the unit should be left connected to 120 volts AC to storebetween uses. To check battery voltage at any time use battery check switch. The battery can also be charged by connecting the DC input to the unit to a van or truck battery or to an external battery charger.

The battery will eventually wear out. Projected life is 2 to 5 years. Indications of a worn out battery are that the unit will only run a short time on battery power. The battery is located in the bottom left front of the unit. To replace the battery remove the screws that hold the front cover with window on the unit. BE SURE to GROUND the three bushings on the high voltage capacitor which is located in the rear before touching an item other than the battery. Remove the polyethylene foam that holds the battery in place.. Disconnect the red “+” lead first. The pull the battery out and take loose the black “-” lead. Disconnect the nylon strap battery holder from the left side by removing the 10-32 nut, #10 lock washer, #10 flat washer, and 1/4 “ flat washer. DO NOT TOUCH ANY INTERNAL PARTS WITHOUT FIRST GROUNDING TO THE CASE! The recommended battery is a 12 volt 17.5 amp hour sealed lead acid. (The unit will run from AC power even when the battery is removed.)

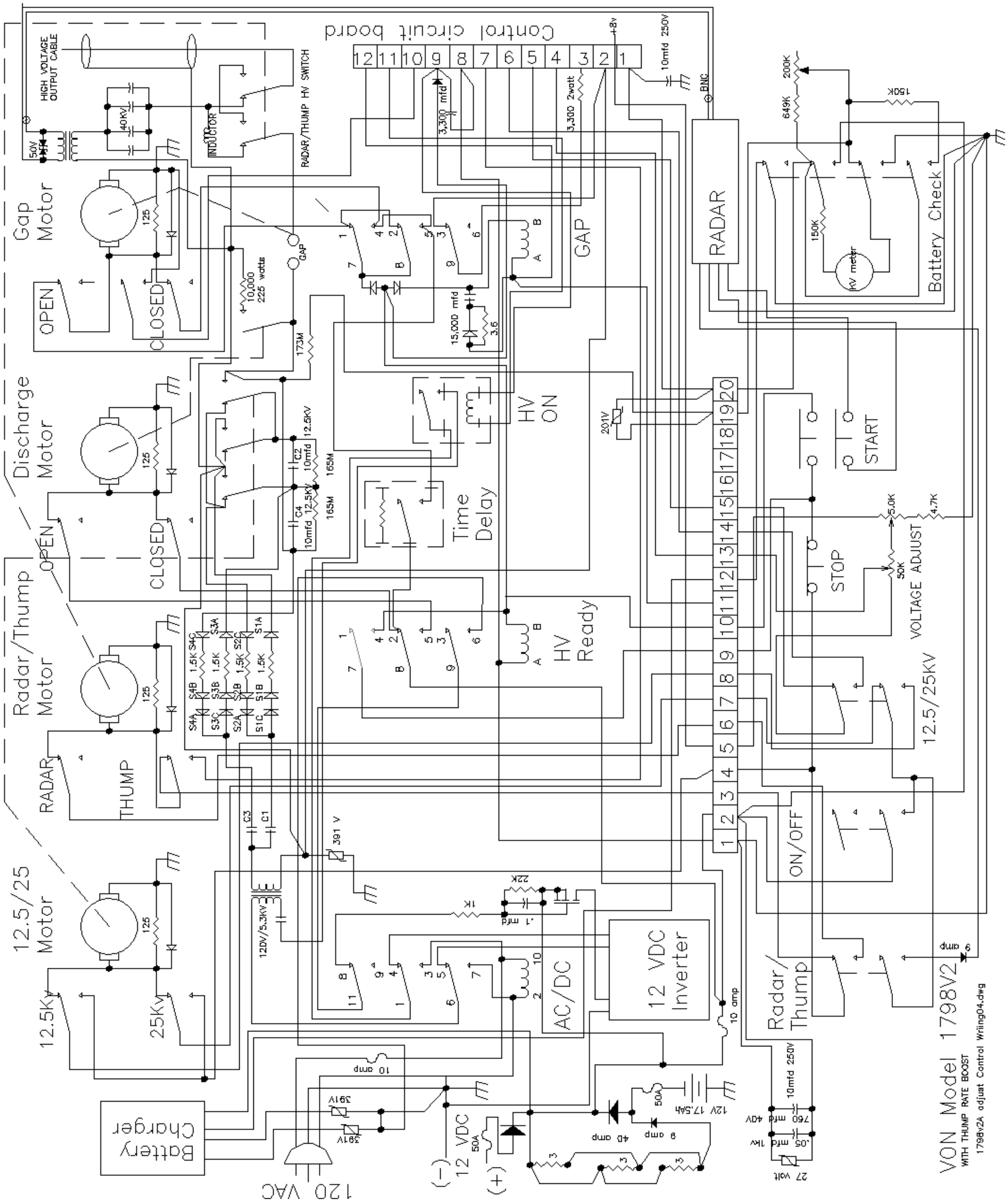
Keep the outer case clean and store in a dry location to prevent corrosion of the internal connections. Tighten any parts or connections that loosen in use.

The unit should be stored plugged into a 120 volt supply.

IX CIRCUIT DIAGRAM AND PARTS LIST

Case	1
Panel, front access with window	1
Capacitor discharge 12.5kv 10 mfd x 2 with silicon oil	1
Capacitor assembly C-1 & C3 (20kv x 2)	1
Switch assembly 12.5/25 with resistive discharge	1
Base plate, red .25" fiberglass	1
Bracket, 6" x .5" x .25 with #10 holes:	1
Bracket 1.125" x 10.5" x .25" fiberglass with slot 9-47/64" from end	1
Switch ends, delrin	2
Switch, moving contact support	1
Bar, brass for switch moving contact	2
Banana plugs	7
Sockets	4
Reducer 1/2-20 x 5/16-24	7
Nuts 1/2-20 thin	7
Discharge end with square hole	1
Discharge end with round .5" hole	1
Rod 1", bottom with 3/8-16 stud	1
Rod 1", top with flat and hole for clevis pin	1
Switch assembly radar/thump with gap	1
Base plate, red .25" fiberglass	1
Bracket, 6" x .5" x .25 with #10 holes:	1
Bracket 1.125" x 10.5" x .25" fiberglass with slot 9-53/64" from end	1
Switch ends, delrin	2
Switch, moving contact support	1
Bar, brass for switch moving contact	2
Banana plugs	7
Socket	4
Reducer 1/2-20 x 5/16-24	7
Nuts 1/2-20 thin	7
Rod 1"diameter x 3.625 with 3/8-16 stud(bottom)	1
Rod 1"diameter x 4.875" with flat and hole for clevis pin	1
Gap end with round .75" hole	1
Gap end with 2.875round .5" hole	1
Tube, teflon 3" OD x 5" long for gap	1
Motor assembly for discharge	1
Bracket, motor	1
Gearmotor 12 rpm 12VDC Grainger #2L008	1
Switch, rigid lever Grainger #6X284	2
Resistor 150 ohms 1 watt	1
Diode 1N4007 1 amp 1,000 volts	1
Rotor, delrin	1
Motor assembly for gap	1
Bracket, motor	1
Gearmotor 12 rpm 12VDC Grainger #2L008	1
Switch, rigid lever Microswitch #MT-4RV-A28	2
Resistor 150 ohms 1 watt	1
Diode 1N4007 1 amp 1,000 volts	1
Rotor, delrin	1
Motor assembly for radar/thump switch	1
Bracket, motor	1
Gearmotor 12 rpm 12VDC Grainger #2L008	1
Switch, rigid lever Grainger #6X284	2
Resistor 150 ohms 1 watt	1
Diode 1N4007 1 amp 1,000 volts	1

Rotor, aluminum	1
Motor assembly for 12.5/25 kv switch	1
Bracket, motor	1
Gearmotor 12 rpm 12VDC Grainger #2L008	1
Switch, rigid lever Microswitch # MT-4RV-A28	2
Resistor 150 ohms 1 watt	1
Diode 1N4007 1 amp 1,000 volts	1
Rotor, aluminum	1
Rod, push 5" x .25" x .5" fiberglass for gap and discharge	2
Rods, push 4.75" x .25" x .5" fiberglass for 12.5/25 & radar thump switch	2
Pin, clevis 1" x 3/16" diameter	8
Pin, cotter 3/16" x 1/2"SS	8
Nut, ½-13 x 1.25" long brass -discharge capacitor terminals	3
Panel control	1
Battery 12 volt 17.5 amp hour gel sel #PS-12180 PSC	1
Battery charger	1
Switch, pushbutton operator #9001SKR1U for START	1
Switch, pushbutton operator # 9001SK5Rfor STOP	1
Switch, pushbutton contact block #KA2 with NO contact	2
Switch, pushbutton contact block #KA3 with NC contact	1
Input power cord	1
Inverter, Statpower	1
Fuse holder BUS #HKP	1
Fuse 10 amps slow blow	2
Resistor 3 ohms 50 watts	3
Resistor 10,000 ohms 225 watts	1
Diode Shotsky, 9 amps 15 volts # 95SQ015-ND	1
Diode, Shotsky 45 volts 45 amps # 40CPQ045	2
Diode MR750	2
Meter, 100 mic DC with scale 0-25 KILOVOLTS	1
Bracket, KV meter	1
Capacitor, .1 mfd 1000 volts ceramic	1
Capacitor 680 mfd 40 volts	1
Capacitor 3,300 mfd 25 volts	1
Capacitor 10,000 mfd 25 volts	1
Relay 12 volts DC 3PDT with light # RR3B-ULDC12	2
Relay 120 volt octal base 3PDT	1
Relay, solid state #GH7008-ND	1
Socket relay 11 pin square IDEC # SR3B-05	2
Socket relay 11 pin octal for AC/DC relay # SR3P-05	1
Terminal 12 position with marker strip	1
Terminal 20 position with marker strip	1
Timer solid state set for 3 seconds	1


Control circuit board
HIGH VOLTAGE OUTPUT CABLE
RADAR/THUMP HV SWITCH
INDUCTOR
Gap Motor
Discharge Motor
Radar/Thump Motor
12.5/25 Motor
OPEN
CLOSED
RADAR
THUMP
12.5Kv
25Kv
GAP
HV ON
Time Delay
HV Ready
RADAR
Battery Check
kV meter
START
STOP
VOLTAGE ADJUST
12.5/25KV
ON/OFF
Radar/Thump
AC/DC
12 VDC Inverter
Battery Charger
120 VAC
12 VDC
VON Model 1798V2
WITH THUMP RATE BOOST
1798v2A adjust Control Wriing04.dwg

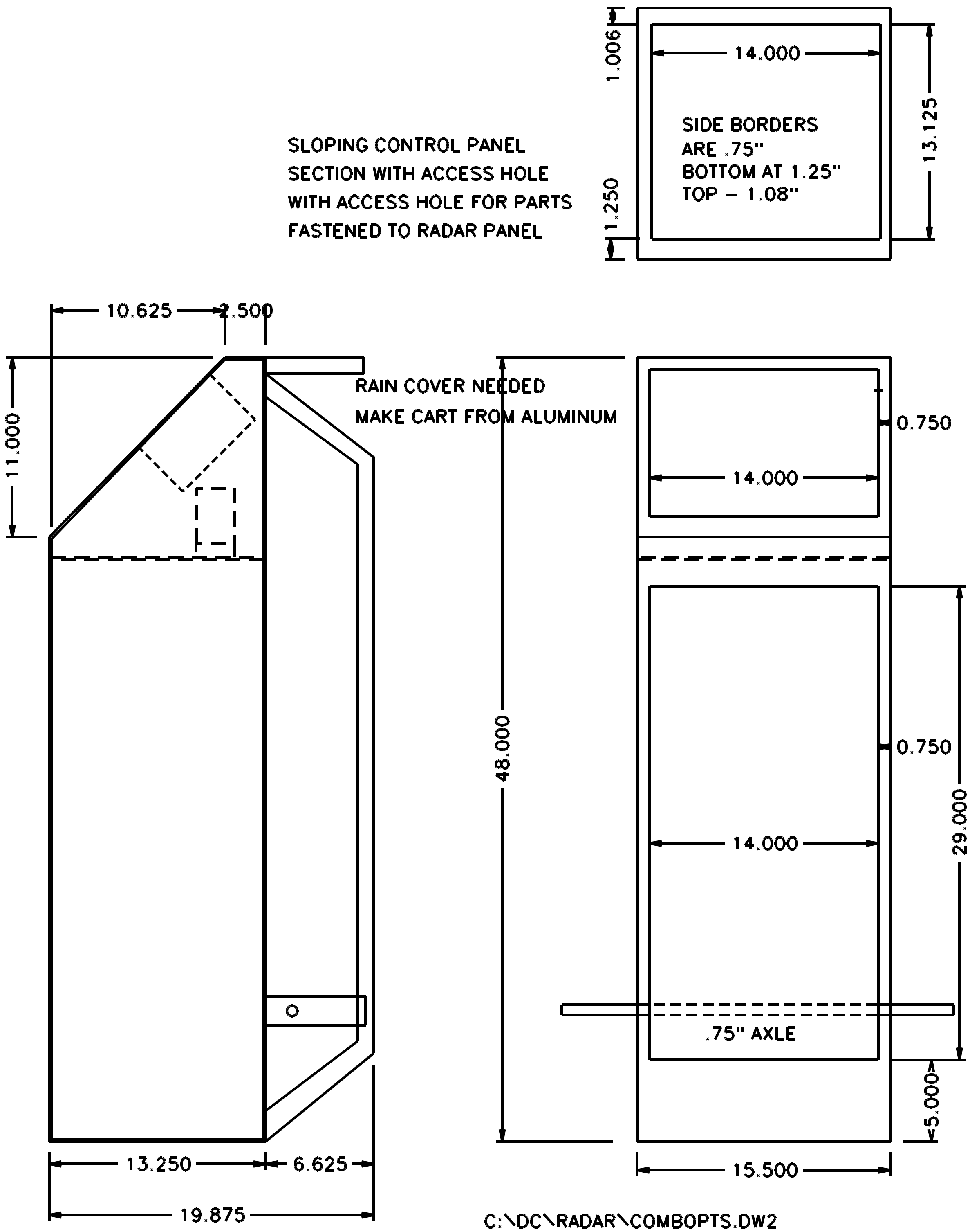


Figure 2 Location of parts internal to the XF25-1563

X RADAR THEORY

Cable radar has been available for over thirty five years. Cable radar is also called the Pulse-Reflection Method, the Pulse-Echo Method, and Time-Domain Reflectometry. Because it works well only on shorts (less than 150 ohms at 10 volts) and opens, it has mainly been used in the telephone industry on communication cable. Radar can be successfully used to locate faults on electric power cable faults by permanently lowering the fault resistance by burning or temporarily lowering the fault resistance using the arc reflection method.

Short duration pulses are transmitted along a cable by a radar. When these pulses reach a discontinuity such as a splice or fault in the cable, a reflection occurs peculiar to the type of discontinuity. By observing these reflections on a CRT or scope and knowing the propagation velocity or the speed at which the pulse travels on the cable, the distance to the discontinuity can be determined. The cable radar is essentially a pulse generator and a cathode-ray oscilloscope. Special circuitry is normally provided with the oscilloscope for determining the distance and for changing the pulse length for different distance ranges.

Pulses are generated and put on a cable that must have consistent distributed capacitance. A reflection will result when a discontinuity or significant change of impedance occurs. An upward reflection or blip would indicate a higher-impedance discontinuity such as the cable ends, or a place where the cable neutral is missing. A downward reflection or blip will result from a lower-impedance discontinuity such a cable fault. The reflection is upwards when the impedance of the discontinuity is above the characteristic impedance of the cable. The reflection is downwards when the impedance of the discontinuity is below the characteristic impedance of the cable.

The characteristic impedance of a transmission line is important since it affects what types of discontinuities will show up on the radar. However it cannot be measured directly with an impedance bridge for a finite length of line. It can be calculated from the distributed-circuit co-efficients of the line at any frequency using the following basic equation.

$$Z_0 = \sqrt{\frac{R + j\omega L}{G + j\omega C}}$$

The equation contains the parameters of resistance, conductance, inductance, and capacitance and is also related to frequency. As the frequency is increased above 1 megahertz, the above equation will reduce to a simplified equation based on the distributed inductance and capacitance; and this simplified equation is shown as follows.

$$Z_0 = \sqrt{\frac{L}{C}}$$

In the case of primary underground cable which acts as a coaxial line we have the published

$$Z_0 = \frac{138}{\sqrt{K}} \log \frac{r_2}{r_1} ohms$$

equation:
K = dielectric constant based on the insulation material
r_1 = inside radius of insulation
r_2 = outside radius of the insulation

Thus the characteristic impedance of the cable varies with the diameter of the cable, thickness of the insulation and the type of insulation. A few common values of Z_0 are 20 ohms for 35kv 1000MCM polyethylene cable, 42 ohms for 35kv 1/0 polyethylene cable, and 74 ohm for RG59U polyethylene cable.

Any change in Z_0 along the length of the cable to the fault will cause reflections. The size of the blip will be based on the reflection coefficient whose maximum value is 1 or -1. The equation for the reflection coefficient p is:

$$p = \frac{Z - Z_0}{Z + Z_0}$$

At the far end terminals with the following impedances:

Z = 0 (short circuit)	p = - 1
$Z >> Z_0$	p = 1
$Z = Z_0$	p = 0
$Z = 1/2\ Z_0$	p = -.33

Thus when the fault impedance exactly equals the cable impedance it will not show up on the screen. Fortunately this almost never occurs in the field.

Distance is figured by a radar using the time delay which is based on how fast the radar pulse travels along the cable. The distance to the fault is related to the time the pulse takes to get to the fault and return. The accuracy of the speed of the pulse in the cable (called the velocity of propagation) determines how accurately the distance to the fault can be calculated.

XI THEORY OF ARC REFLECTION METHOD

The arc reflection method utilizes the low resistance path to ground (less than 50 ohms) created at the cable fault by an arc. The arc is provided by a capacitor discharge fault locator (thumper) to temporarily display the fault on a standard radar. Using the low resistance of an arc overcomes the main limitation in the past of radars which alone could not see the high resistance faults most common in underground primary power cable. The arc reflection method does not overcome the limitations of radar itself. The operator must become proficient in the use of the radar especially in recognizing faults near the ends of the cable. On cable with missing neutral, a cable radar may not even show the far end of the cable. Because of the time it takes for a reflection on the radar to recover to the zero level, the operator must be skilled when locating faults near discontinuities in the cable such as splices or the cable terminals. The radar is connected to the faulted cable through a coupler(filter) and displays the low resistance at the fault as a down blip during the time of the arc. The coupling system performs three functions.

1. Induce the high frequency radar signal onto the faulted cable through high voltage isolation required to protect the radar.
2. Provide a wave trap so the radar does not see the low impedance of the impulse fault locator with each discharge.
3. Lengthen the impulse with a large air coil inductor so that it provides current to the arc at the fault for a longer time so the fault position can show up on the radar. The inductor keeps the current flowing into the low resistance arc until the charge in the capacitor bank is dissipated. Increasing the size of the capacitor bank in the impulse fault locator lengthens the pulse and thus the time of the arc at the fault.

When the radar signal is induced on the cable, all discontinuities in the cable such as splices, change in cable insulation, change in neutral construction, connected transformers, and ends show up on the radar screen.

This system:

1. Reduces the number of thumps required to pinpoint a cable fault.
2. Uses standard radar so operator training is simplified.
3. Shows cable ends and splices so that an approximate location can be determined looking at the screen.
4. Provides the conductor distance to the fault. Only the conductor distance is displayed. Actual ground distances are subject to variations caused by the cable route and the cable depth. The accuracy of any distance determined by the radar is dependent on the correct velocity of propagation and the operator's skill.

XII CABLE DISTANCE MEASUREMENTS

The distance provided by a radar is conductor distance not ground distance. Accuracies of 2% of cable length are possible but not often achieved. Information is provided in this section on how to get the most accuracy using the radar. For maximum accuracy use the two terminal method where the fault distance is determined from both ends of the cable. The fault will be between both marks made using these distances.

All distances provided by a radar are determined using time measurements based on the speed at which the pulses move up and down the cable. The pulse speed is based on characteristics of the cable such as conductor size, shielding type, insulation thickness, eccentricity, and insulation material. The speed changes as the cable insulation ages. If the neutral shield is solid, the dielectric constant of the insulation is the determining factor in the velocity of propagation. For maximum accuracy, the speed (or time) must be determined from a known length of cable with identical characteristics to the cable being worked upon. This speed is entered into each radar in several forms. The speed is normally compared to the velocity of an ideal conductor in free air of 983 feet/microsecond.

To determine the true velocity of propagation or velocity of propagation factor of a cable the following procedure is recommended.

1. Connect the radar to a cable of known length, size, insulation type, shielding type and condition. Unburied cable is best since the actual cable length can be measured accurately. Buried cable lengths are less accurate due to the allowances that must be made for cable depth and coils of wire put at the ends to handle future expansions.
2. Use the turn on velocity factor or set the propagation velocity factor to an assumed value or the value of a similar cable obtained from a chart such as that found in the end of this section.
3. Short to the cable neutral at both the near end HV lead connection point and the far end to identify these points on the radar screen.
4. Determine the total length to the end of the cable being measured.
5. To determine the true propagation velocity or propagation velocity factor, multiply the assumed propagation velocity for propagation velocity factor by the actual cable length and divide by the measured cable length.

$$\frac{\text{Assumed propagation velocity x actual cable length}}{\text{Cable length measured with the radar}} = \text{True Propagation Velocity}$$

6. Reset the radar with the True Propagation velocity determined above. Repeat steps 3 and 4 to verify that the measured cable length equals the actual cable length

.
The propagation velocity factor is determined by dividing the actual velocity of propagation in feet/microseconds by 983. Some representative values are shown below.

INSULATION TYPE & CONDUCTOR SIZE	INSULATION THICKNESS AND TYPE	PROPAGATION VELOCITY FACTOR
XLPE- 1/0	175 mil insulation	.562
XLPE- 1/0	260 mil insulation	.555
XLPE- 1/0	345 mil insulation	.623
XLPE- 1/0	345 mil water impervious	.582
EPR- 1/0	345 mil	.588
XLPE- 400kcmil	260 mil water impervious	.643
XLPE- 600kcmil	260 mil	.598
XLPE- 750kcmil	345 mil-CN	.562
XLPE- 1000kcmil	260 mil-CN or Jacketed	.600
XLPE- 1000kcmil	260 mil water impervious	.541
air- most common sizes		.98
PILC- most common sizes		.38
EPR- range of sizes		.55-.62
HMWP- range of sizes		.52-.58
XLPE- range of sizes		.49-.64

The fault can be located by the following two methods even when the velocity of propagation is not known.

The comparative method of locating a fault using radar utilizes the fact that an overall length of the cable is known or a specific distance is known to a splice or landmark such as a transformer. Determine the distance to the fault with the radar. Then determine the distance to the known point with the radar. Using the following formula, the actual distance to the fault can be determined.

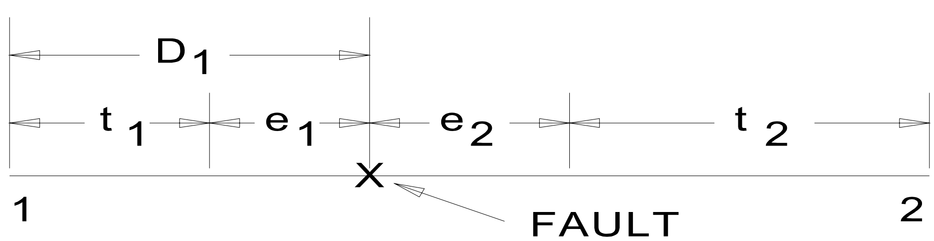
$$D_1 = \frac{t_1}{t_2} \times D_2$$

Where D_1 = Actual distance to the fault
D_2 = Actual distance to known point
t_1 = Distance provided by radar to fault
t_2 = Distance provided by radar to known point

The three stake method or two terminal method of locating faults is used when the velocity of propagation or a specific distance is not known. This method can also be used whenever maximum accuracy is required.

a. Take a reading from one end of the cable to the fault. Measure out the distance with a wheel and drive a stake.
b. Without changing the propagation velocity on the radar take a reading from the opposite end of the cable. Again measure out the distance with a wheel and drive a stake.
c. The fault will lie between the two stakes. By using the following formulas, the fault location can be determined.

Where D_1 = Distance to the fault
t_1 = Radar distance reading from point 1
t_2 = Radar distance reading from point 2
e_1 = Error distance between t_1 and the actual distance to the fault D_1
e_2 = Error distance between t_2 and the actual distance to the fault
$(e_1 + e_2)$ = Distance between stakes



FAULTED CABLE

$$D_1 = t_1 + e_1$$

$$e_1 = \frac{t_1 (e_1 + e_2)}{t_1 + t_2}$$